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ENVELOPE ELIMINATION AND RESTORATION LINEAR AMPLIFIER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an envelope elimination and restoration linear amplifier.

2. Brief Description of Related Developments

The present trend in portable communications devices such as mobile telephones is to increasingly lightweight devices with increased talk-time between battery recharge cycles. Such developments require ever more efficient radio-frequency (RF) amplifiers to minimise power consumption. In cellular systems such as GSM, the modulation scheme is a constant amplitude scheme, also referred to as constant envelope modulation, which permits use of efficient non-linear amplifiers. However, recent types of communication system such as EDGE and UMTS use non-constant envelope modulation schemes. The drawback is that the amplification of non-constant envelope RF signals requires the use of linear power amplifiers, which are inherently less efficient. The lower power efficiency of linear amplifiers translates into higher power consumption and higher heat dissipation.

A variety of linearisation architectures and schemes exist, including fixed and adaptive pre-distortion, adaptive bias, envelope elimination and restoration, polar loop and cartesian loop transmitters. Details of such devices are shown in "Increasing Talk-Time with Efficient Linear PA's", IEE Seminar on TETRA Market and Technology Developments, Mann S, Beach M, Warr P and McGeehan J, Institution of Electrical Engineers, 2000, which is incorporated herein by reference. However, many of these devices and techniques are unsuitable for battery operated portable devices such as mobile telephones, or are incapable of meeting current RF design standards, such as the TETRA

linearity standard, ETSI publication ETS 300 396-2; "Trans-European Trunked Radio (TETRA); - Voice plus Data (V+D) – Part 2: Air Interface (AI)"; March 1996.

Envelope elimination and restoration (EER) transmitters separate envelope and phase information from an input modulated signal. The phase information is then passed through a power amplifier as a constant envelope signal, permitting the use of efficient, non-linear amplifiers, while the envelope signal is added to the power amplifier output. In order to correct AM-PM distortion, phase feedback is employed and the power amplifier is effectively placed within a phase-locked loop.

The envelope of the output signal is controlled by another feedback loop. Predistortion has been used to improve stability of the loops. However, the predistortion required is dependent on power level and does not correct for errors in the feedback path.

SUMMARY OF THE INVENTION

According to the present invention, there is provided an envelope elimination and restoration linear amplifier comprising an envelope control loop including a feedback path, wherein the gain of said feedback path is variable for controlling the gain of the amplifier.

Consequently, the predistortion required is independent of the output power level. Also, where the amplifier is used as the RF power amplifier of a transmitter, there are improvements with respect to adjacent channel power and EVM/phase error.

The gain of the feedback path may be controlled by means of a variable gain amplifier and/or a variable attenuator. Such circuits are well-known in the art.

Preferably, the amplifier includes a phase control loop. More preferably, the feedback path is shared by the envelope control and phase control loops.

Preferably, the feedback path includes downconverter means for downconverting the frequency of the feedback signal therein. More preferably, the feedback path includes gain control means before the downconverter means.

Preferably, the gain of the feedback path is electronically controllable. More preferably, the feedback path comprises variable gain means responsive to a control signal to set its gain.

The present invention is particularly applicable to the RF power amplifiers of communications devices, e.g. mobiles phones. Preferably, such devices include control means for determining a desired output power and providing a corresponding control signal to the amplifier.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a perspective view of a mobile telephone handset;

Figure 2 is a schematic diagram of mobile telephone circuitry for use in the telephone handset of Figure 1; and

Figure 3 is a block diagram of an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings.

Referring to Figure 1, a mobile station in the form of a mobile telephone handset 1 includes a microphone 2, keypad 3, with soft keys 4 which can be

programmed to perform different functions, an LCD display 5, a speaker 6 and an antenna 7 which is contained within the housing.

The mobile station 1 is operable to communicate through cellular radio links with individual public land mobile networks (PLMNs) operating according to communication schemes such as UMTS and EDGE.

Figure 2 illustrates the major circuit components of the telephone handset 1. Signal processing is carried out under the control of a digital micro-controller 9 which has an associated flash memory 10. Electrical analogue audio signals are produced by microphone 2 and amplified by pre-amplifier 11. Similarly, analogue audio signals are fed to the speaker 6 through an amplifier 12. The micro-controller 9 receives instruction signals from the keypad and soft keys 3, 4 and controls operation of the LCD display 5.

Information concerning the identity of the user is held on a smart card 13 in the form of a GSM SIM card which contains the usual GSM international mobile subscriber identity (IMSI) and an encryption key K_i that is used for encoding the radio transmission in a manner well known per se. The SIM card is removably received in a SIM card reader 14.

The mobile telephone circuitry includes a codec 15 and an rf stage 16 including a power amplifier stage 17 feeding the antenna 7. The codec 15 receives analogue signals from the microphone amplifier 11, digitises them into an appropriate signal format and feeds them to the power amplifier stage 17 in the rf stage 16 for transmission through the antenna 7 to the PLMN shown in Figure 1. Similarly, signals received from the PLMN are fed through the antenna 7 to be demodulated in the rf stage 16 and fed to codec 15, so as to produce analogue signals fed to the amplifier 12 and speaker 6.

Referring to Figure 3, the power amplifier stage 17 comprises an envelope elimination and restoration (EER) amplifier 18 which separates the envelope and phase components of an input modulated IF signal into two separate forward

paths 19, 20. A common feedback path 21 is used for control of both the envelope and phase components of the RF output by the amplifier stage 17.

The envelope forward path 19 comprises first and second envelope detectors 22, 23 which detect the envelopes of the input modulated IF signal and the feedback signal from the feedback path 21 respectively. The outputs of the envelope detectors 22, 23 are fed to respective inputs of a comparator 24. The output of the comparator 24 is filtered by a low-pass filter 25 and applied to an envelope controller 26.

The envelope controller 26 comprises a fast power supply modulator which directly modulates the supply voltage of the actual power amplifying part 27.

The phase forward path 20 comprises first and second limiters 28, 29 which limit the input modulated IF signal and the feedback signal respectively to produce respective constant-amplitude signals. The constant amplitude signals are applied to a phase detector 30 and the output of the phase detector 30 is filtered by a low-pass filter 31 and applied to a voltage-controlled oscillator 32 as is conventional in a phase-lock loop. The RF signal produced by the voltage-controlled oscillator 32 is input into the power amplifying part 27 which amplifies it in dependence on the signal input to the envelope controller 26.

The output of the power amplifying part 27 is fed to an antenna and a variable gain amplifier 33. The output of the variable gain amplifier 33 is connected to one input of a mixer 35. The other input of the mixer 35 receives a local oscillator signal. The output of the mixer is low-pass filtered by a feedback path filter 36 to select a low frequency mixing product. Thus, the mixer 35 and filter 36 act to down convert the RF output of the amplifying part 27 to the IF signal frequency.

The output of the feedback path filter 36 is fed to the inputs of the second envelope detector 23 and the second limited 29 to complete the feedback paths of the envelope and phase control loops.

In operation, the IF input is provided at a constant level, irrespective of the output power level required, and with a constant predistortion applied by a predistortion circuit 37. The predistortion required will depend on the particular circuitry employed and the technique is well-known in the art. The output power of the power amplifying part 27 is controlled by controlling the gain of the variable gain amplifier 33. The gain of the variable gain amplifier 33 is set by a power control signal (P) from the mobile phone's controller 9 (Figure 2).

It will be appreciated that if the gain of variable gain amplifier 33 is reduced, the output power of the power amplifying part 27 will increase and vice versa.

It will be appreciated that many alterations to the above-described embodiment may be made.

What is claimed is: